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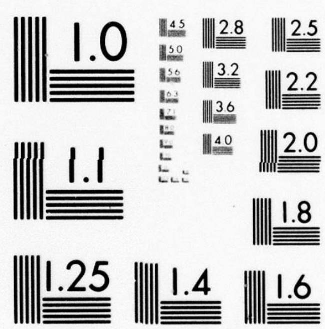
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AWS/TN-79/001
Vol. IV

AIR WEATHER SERVICE

SPECTRAL RADIOMETRIC MEASUREMENT AND ANALYSIS PROGRAM

SCAT3
Operator's Manual

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April 1979
Final Report

Approved for Public Release; Distribution Unlimited

Prepared for
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Scott AFB, Illinois 62225

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GROUND-BASED RADIOMETRY

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report covers ~~Eastman Kodak Company~~ recently completed a contract with the United States Air Force Air Weather Service to conduct research into the transfer of atmospheric energy in the visible and near-infrared portions of the electromagnetic spectrum. Its objective was to produce a spectral model of path transmittance, radiance, and ground-level irradiance that could be related to meteorological observations through the use of simultaneous, in-situ data collections. For this purpose a mathematical model was developed. CONT

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It was based on physical equations for a homogeneous atmosphere that were modified by empirical observations made under a broad range of meteorological conditions. With the model it is possible to estimate the visible and near-infrared spectral absorption and scattering phenomena that result from atmospheric constituents, from surface synoptic weather observations. The atmospheric model was coded into a computer program called SCAT3.

This document is the fourth volume documenting the radiometric data collection program that culminated in the radiometric atmospheric model, SCAT3. The objective of this volume is to acquaint the user with the proper input sequences and options when SCAT3 is run on an IBM 370 computer. Volumes, 1, 2, and 3 contain the details of data collection, analysis, and derivation of equations that were coded into the program to reconstruct atmospheric radiance, transmittance, and ground irradiance.

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SECTION 1

GENERAL DESCRIPTION OF SCAT3 PROGRAM

1.1 INTRODUCTION

SCAT3 is a special version of Program SPECTR, a general purpose program for manipulating optical, photographic, and electro-optical elements on a wavelength-by-wavelength basis. Each element is represented by an array of values representing, for instance, transmittance, reflectance, or relative sensitivity for a 5 nm portion of the spectrum (300-1200 nm). These elements may be added, multiplied, integrated, etc, to model the response of a system. A disk-based library of elements provides flexibility in modeling a wide variety of components and systems. In addition to handling array values, the program may also use temporary constants.

SCAT3 contains an *atmospheric simulation model* based on the collection program and data analysis discussed in detail in Volumes 1, 2, and 3. The atmospheric model is contained in a series of subroutines, commanded by an operator command function, AMOS. The output of the AMOS function is a series of spectral elements describing atmospheric path transmittance and radiance, various forms of ground-level irradiances, and several other spectral radiometric quantities that can be used in subsequent computations. User function SYSINT VFUN is available for performing a series of calculations and integrations of AMOS elements,and elements that define a system-sensor response.

1.2 OPERATING COMMANDS

The SCAT3 Program, in its basic form, supports four commands which in turn support the functions shown in Figure 1-1. These commands are summarized below and described in detail in the following four sections of this volume:

a. AMOS generates temporary elements for atmospheric computations, based on surface weather, solar altitude, etc.

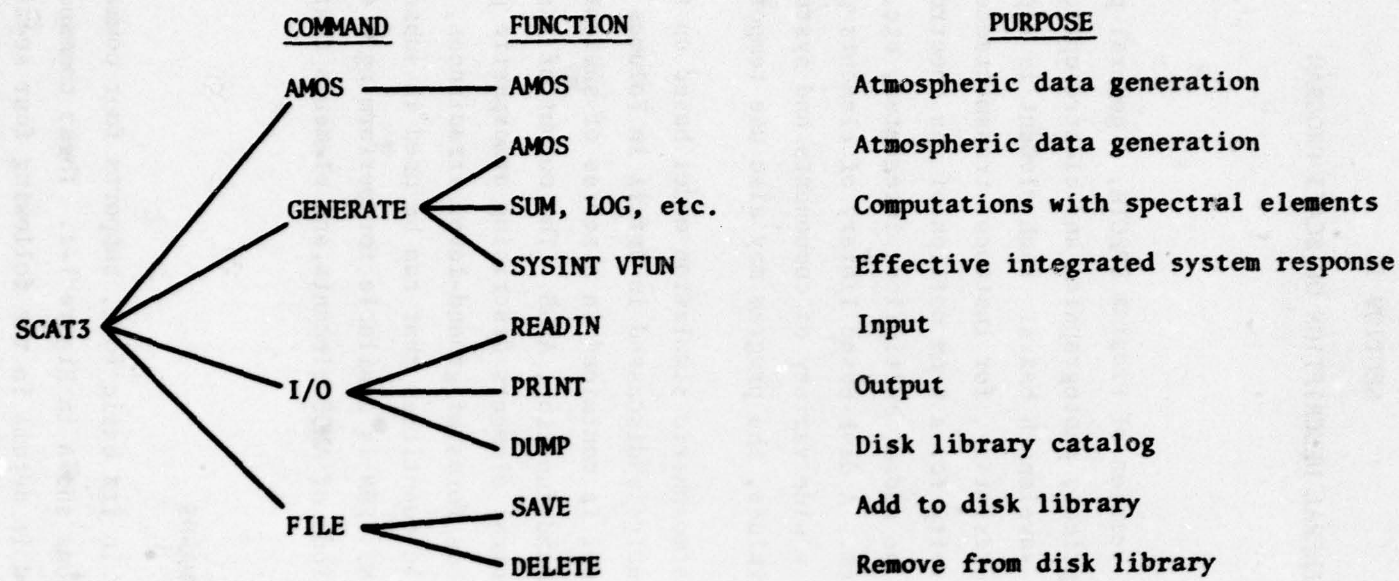

Figure 1-1. SCAT3 Commands and Functions

b. GENERATE generates temporary elements that are the result of computations; e.g., special functions such as AMOS, or the user function SYSINT VFUN. The command GENERATE SCAT3 AMOS is equivalent to AMOS.

c. I/O (Input/Output)is used to read in or print out spectral elements.

d. FILE is used for disk file maintenance. It is normally used to save spectral elements in the library or delete elements when they are no longer needed.

Although SCAT3 has a multiplicity of optional functions, only the following four basic command sequences are used:

a. GENERATE SCAT3 AMOS,or simply AMOS

b. GENERATE SYSINT VFUN

c. I/O READIN

d. FILE SAVE or FILE DELETE

The various other options are not used in routine operation of the SCAT3 program and have therefore been grouped for further discussion in Section 6.

1.3 EXAMPLE OF A TYPICAL PROGRAM RUN

To set up program SCAT3, a series of command and associated data cards are used. Each command card (e.g., GENERATE ...) must begin in column 1 of the card. If the particular function does not require a data card, subsequent command cards for the same function may have a blank in column 1 instead of the command name. An 80-column layout sheet for the command and data cards for a typical run are shown in Figure 1-2. The purpose of each command sequence in the example in Figure 1-2 is summarized below. This sequence exercises all the required commands in the normal operation of SCAT3.

(1) Read-in a new detector spectral sensitivity element to be stored by the name DET78.

(2) Peak-normalize DET78, and store the normalized spectral element, by the name DET78, in the disk file.

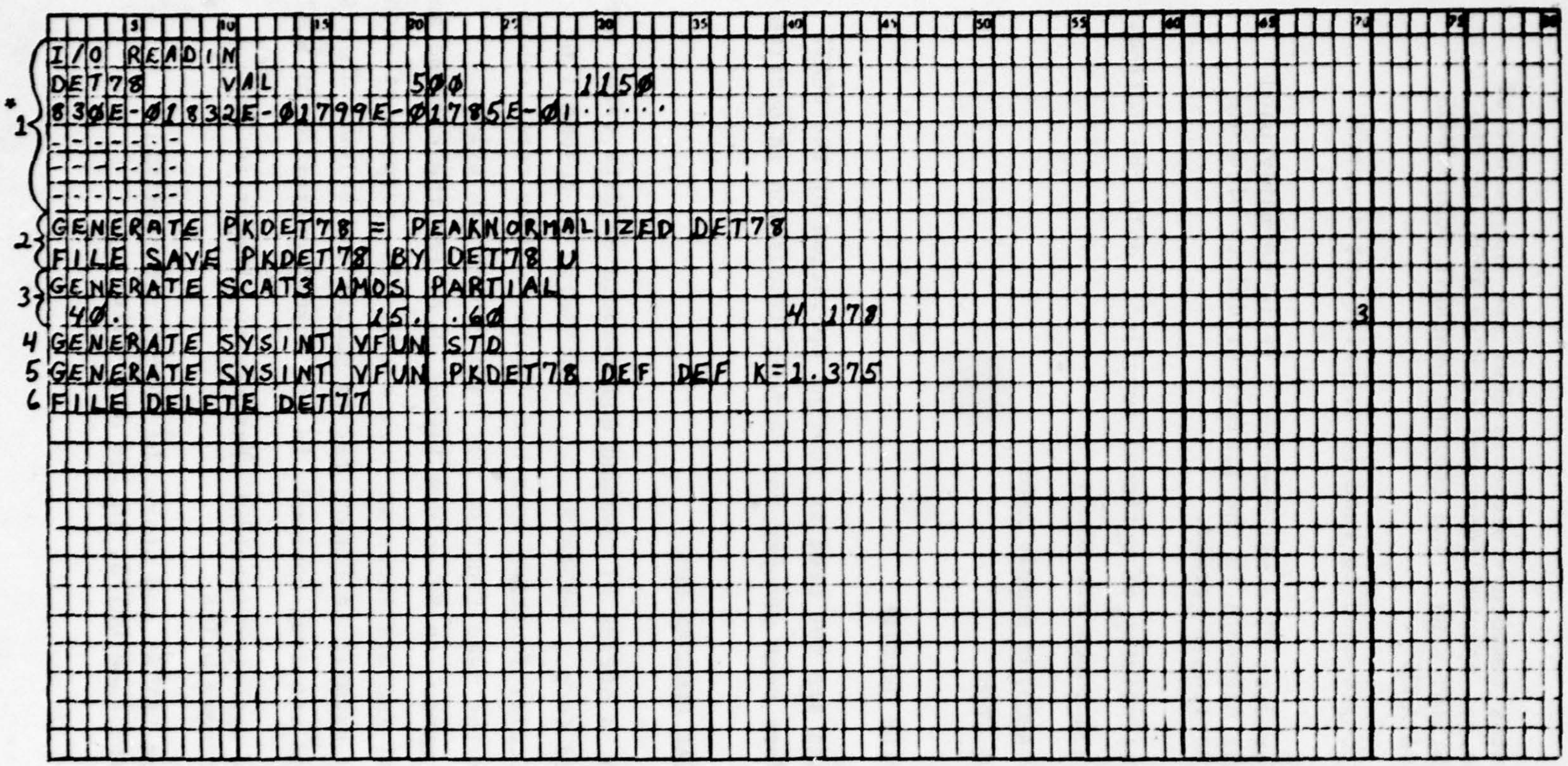

Figure 1-2. Example of Correctly Formatted Input Cards for SCAT3 Operation

* See text for explanation of example.

(3) Generate the atmospheric and ground level irradiance spectral elements corresponding to the following: solar altitude of 40 degrees, surface temperature of 15 degrees Celsius, relative humidity of 60%, forest surround, and all other parameters having default* values for the date 4/1/78.

(4) Spectrally integrate the elements DH, T, and SK, etc, with the default spectral elements for detector, lens, and scene reflectance.

(5) Repeat the spectral integrations, substituting the normalized detector array PKDET78 for its default element. Multiply the results by the factor 1.375. The lens and scene reflectance elements remain unchanged.

(6) Delete the element DET77 from the disk library.

* If no input specification is given, the program will assume certain values of parameters and spectral element arrays.

SECTION 2

DESCRIPTION OF THE COMMAND AMOS

2.1 GENERAL DESCRIPTION

The AMOS command allows the user to generate spectral elements that describe the atmosphere based on estimated surface meteorology, solar altitude, acquisition geometry, and other factors. These spectral elements can be used in subsequent functions, such as SYSINT VFUN, I/O FILE, etc.

2.2 INPUTS

Each run of AMOS requires a command card that defines print options, and a data card. The data card provides the values for the input variables that are needed to generate the spectral atmospheric and ground irradiance elements. All options and values have defaults except for solar altitude and weather/transmittance estimates. The input values are checked for reasonableness, and warnings or fatal error-condition messages may be written, depending on the seriousness of the error.

The user may specify the amount of printout from an AMOS run. The choices are: FULL, which prints all 8 spectral-array elements; PARTIAL, which prints only atmospheric path transmittance (T), atmospheric path radiance (SK), and horizontal daylight irradiance (DH); and NONE, which prints no array elements. The input and default variables are printed regardless of the option selected.

2.2.1 Command Card

The three valid AMOS commands that serve to illustrate the print options (see Figure 2-1) are:

a. GENERATE SCAT3 AMOS NONE, or AMOS NONE
b. GENERATE SCAT3 AMOS PARTIAL, or AMOS PARTIAL
c. GENERATE SCAT3 AMOS FULL, or AMOS FULL.

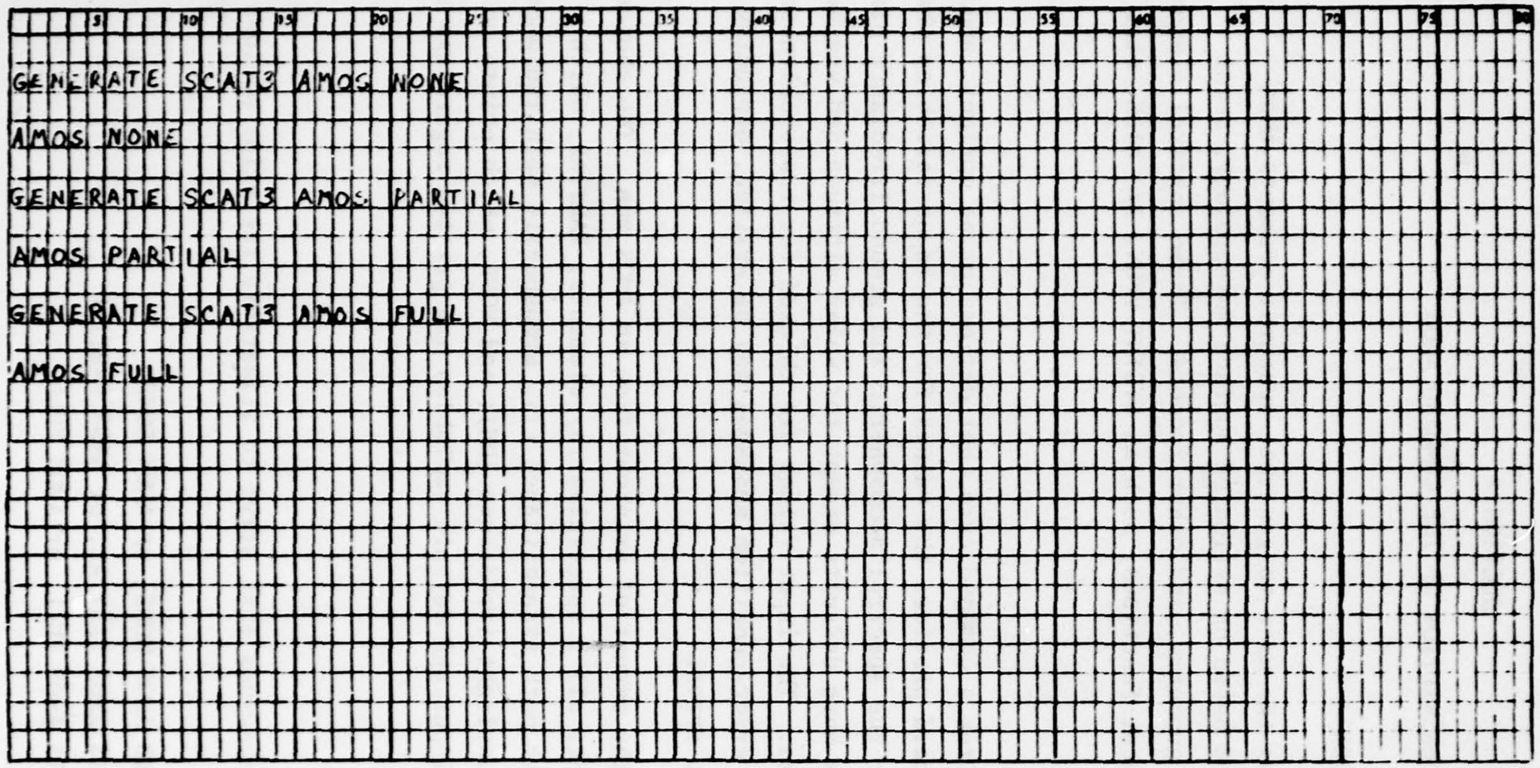

Figure 2-1. Examples of Correctly Formatted Command Cards

2.2.2 Data Card

Each AMOS command card must be followed by a single data card having the format and definition of input variables shown in Tables 2-1 and 2-2. When a run is set up, the user must be sure that any values that he lets default match the desired run conditions. The program can be operated using one of three types of input variables.

<u>Surface Weather</u> for which the inputs are surface relative humidity, temperature in degrees centigrade, and pressure corrected to sea level, in millibars.

<u>T550</u> for which the single input is an estimate of the vertical-path atmospheric transmittance at 550 nm wavelength, and

<u>Precipitable Moisture</u> for which the simple input is the integrated partial pressure of water in a vertical column of atmosphere, expressed in centimeters.

These input options are mutually exclusive, and if input variables are specified for more than one mode, error messages will be generated and the AMOS run will possibly be terminated. Valid data cards that illustrate use of the AMOS atmospheric options are shown in Figure 2-2.

TABLE 2-1

FORMATS AND DEFINITIONS OF DATA CARD PARAMETERS

Column	Format	Name of Variable	Definition
1-5	F5.1	RSA	The solar altitude above the local horizon. Its valid range is between -5° and 90°. Below 5° this value is adjusted for refraction to obtain apparent solar altitude.
6-10	F5.1	OBS	The observation zenith angle. It is defined as the angular displacement of the look vector from local zenith. The valid range is 0° to 90° where 0° represents a downward vertical ray vector.
11-15	F5.1	CATS	The angle between the observer and the sun's vector. It has a valid range of 0° to 180°. If no value is specified and ZA = 0° (vertical), a value of 90°-RSA will be assumed.
17-20	A4	TCH	Surface temperature in degrees celsius. Its valid range is -50°C to +50°C. If the temperature is not specified, a value of 20°C is assumed. The decimal point <u>must</u> be included in any value.
21-24	F4.2	RH	Relative humidity indicated as a decimal fraction. Its valid range is 0-1.0. If percent humidity is specified, it will be converted to decimal format.
25-30	F6.0	PSL	Atmospheric pressure at the station reduced to sea level, in millibars. The valid range is 500-1200 MB. The default is 1 standard atmosphere, or 1013.25 MB. Values given in inches of mercury (which may be a number less than 32) will be converted to millibars.

TABLE 2-1 CONT'D

Column	Format	Name of Variable	Definition
31-34	A4	T55CH	The estimate of vertical transmittance at 550 nm (T550). It may be specified as a value between 0.2 and 0.815, or as "TAVG" (0.740) or "RAYL" (Rayleigh atmosphere, w/DUST, = 0). If either precipitable moisture (PM) or relative humidity (RH) is specified, no entry is required.
35-38	F4.2	OZ	Ozone scale height in millimeters. If no value is specified, OZ is estimated on the basis of latitude, altitude, and elevation.
39-44	3I2	MO, DAY, YR	Date, in terms of month, day, and year (e.g., 101578, for October 15, 1978). If the month and day are inverted in an unambiguous manner (e.g., 24 278), it will be corrected to 2/24/78. The default date is the computer run date.
45-48	F4.0	LAT	Latitude. The valid range is 1° to 90° for the northern hemisphere.
49-55	F7.2	ELEV	The station elevation in kilometers. A value greater than 500 is assumed to be in feet and is converted to km. The default is 0 (sea level).
56-65	F10.2	ALT	The altitude of the observer above the station in kilometers. A value greater than 500 is assumed to be in feet and is converted to km. The default is 150 km.
66-69	F4.2	ARFL	The albedo reflectance of the station surroundings at 650 nm expressed as a decimal fraction (e.g., 0.26). The valid range of 0 - 1.0. If percent reflectance is used, it will be converted to decimal format. The default depends on the albedo type specified.*

* See Table 2-2 for the albedo default reflectances.

TABLE 2-1 CONT'D

Column	Format	Name of Variable	Definition
70	I1	ITYP	The albedo type, showing 1 for desert, 2 for snow, 3 for forest, and 4 for urban/industrial (default). For each type there is an appropriate default albedo reflectance, which may be overridden by a value in the previous field.
71-75	F5.2	DUST	Dust in particles/cubic centimeter. If not specified, a value is estimated from the precipitable moisture.
76-80	F5.2	RPM	Precipitable moisture in cm. If not specified, it is estimated from atmospheric transmittance, or temperature and relative humidity.

TABLE 2-2

ALBEDO TYPES AND DEFAULT REFLECTANCES

Desired Albedo	ITYP (Col. 70)	Default ARFL*
Desert	1	.385
Snow	2	.735
Forest	3	.084
Urban/Industrial (default)	4	.125

* The decimal reflectance at 650 mm, which is multiplied by a spectral array selected by ITYP that is normalized at 650 mm.

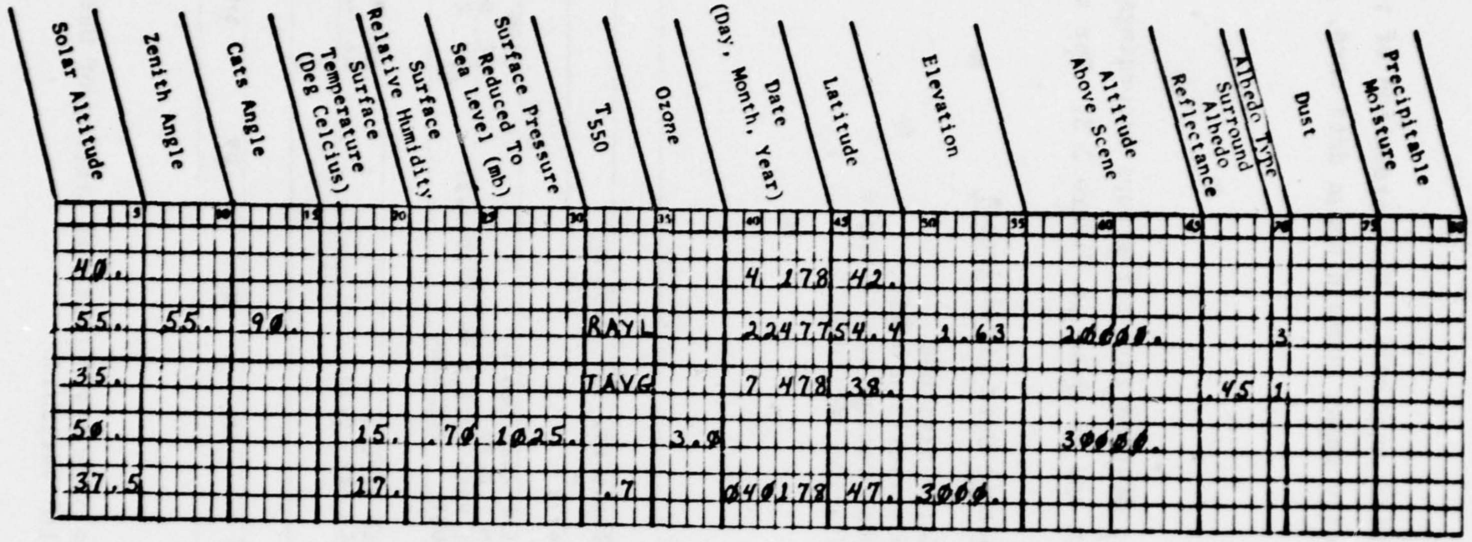

Figure 2-2. Example of Correctly Formatted Data Cards

2.3 OUTPUT

The output of SCAT3 is printed copy only. Each execution of the program, which results from a correctly input command and a data card, generates the output described below.

2.3.1 Data Card Variables

The listing of variables is divided into six groups accordings to the way they operate in the program and as shown in Figure 2-3. The six variable groups are:

1. Trigonometric Data (in degrees)

   SA: Solar altitude
   CATS: Observer-sun angle
   ZA: Observation zenith angle
   LAT: Station latitude

```
GENERATE SCAT3 AMOS FULL

                  CONVERTED  10000.0 FT. TO    3.05 KM

                      DATE:  5/ 6/78

  SA    40.0  ( 40.0)       TEMP 20.0 DEG C                    T550  0.740   TAVG
  CATS  50.0                RH    0.79                         OZ   0.08
  ZEN    0.0                SL PRES 1013.3 MB  ( 1013.3)       PW   2.274 CM
  LAT   39.0                DUST     2.2 P/ML

  ELEV   0.0   KM           ALB TYPE 4                         KR   -0.00255
  VA    3.048               ALB REF  0.13                      KA   -0.14337
                                                               C     1.014
                                                               W     1.900

  GENERATES:
     T          TV        ALB        SK        DH        DV        SH        SVB
```

Figure 2-3. Example of SCAT3 Output and Listing of Data-Card-Specified Variables

2. Surface Weather Data

TEMP: Temperature (°C)
RH: Relative humidity
SL PRES: Station pressure corrected to sea-level (mb)
DUST: Surface dust concentration (part/cm^3)

3. Alternative Scaling Parameters

T550: Vertical atmospheric transmittance at 550 nm
OZ: Ozone scale height (cm)
PM: Total vertical column of precipitable moisture; sea-level to space (cm)

4. Elevation Data (km)

ELEV: Station elevation above sea-level
VA: Observer's altitude above station elevation

5. Surround Reflectance Parameters

ALB TYPE: Description of station surrounding (i.e., vegetation, sand, snow, industrial)

ALB REF: Surround reflectance at 650 nm

6. Atmospheric Transmittance Parameters

KR: Rayleigh scattering coefficient
KA: Aerosol scattering coefficient
C: Exponent for aerosol scattering term
W: Precipitable moisture between station and observer's elevation (cm)

2.3.2 Spectral Arrays

In addition to the data card variables, the spectral arrays and their numeric codes that were generated as a result of these input data card variables, are also printed.

These arrays can be recalled from temporary program data files to operate on the spectral data in subsequent calculations. The arrays are not permanently stored and are written over upon the execution of a subsequent GENERATE command. The eight spectral arrays grouped by type are listed below.

Atmospheric Path Transmittance (350-1150 nm)

T: Oblique spectral transmittance (scattering plus absorption) from the observer's altitude to ground, adjusted for precipitable moisture, dust, path length, and terrain elevation.

TV: Vertical spectral transmittance (scattering plus absorption) from the observer's altitude to ground, adjusted for precipitable moisture, dust, and terrain elevation.

Atmospheric Path Radiance (350-1150 nm)

SK: Spectral atmospheric path radiance, at the specified angles, adjusted for observer's altitude, terrain elevation, surround albedo, precipitable moisture,(watts/m^2/steradian/5 nm).

Terrain Reflectance (350-1150 nm)

ALB: Spectral reflectance of the station surround based on the albedo type and normalizing reflectance that is input.

Ground Level Irradiance (350-1150 nm)

DH: Daylight irradiance on a horizontal surface adjusted for solar altitude, atmospheric transmittance, and surround albedo (watt/m^2/5 nm).

SH: Skylight irradiance on a horizontal surface from the full hemisphere minus direct sunlight adjusted for solar altitude, atmospheric transmittance, and surround albedo (watts/m^2/5 nm).

DV: Daylight irradiance on a vertical surface perpendicular to the solar azimuth adjusted for solar altitude, atmospheric transmittance, and surround albedo (watts/m^2/5 nm).

SVB: Skylight irradiance on a vertical surface perpendicular to and 180° away from the sun azimuth adjusted for solar altitude, atmospheric transmittance, and surround albedo (watts/m^2/5 nm).

Figure 2-4 shows a typical spectral array generated by the AMOS subroutine. Although only three such arrays are printed under the PARTIAL print option, all eight arrays are internally generated and available for further computer operations.

VALUES FOR DH

		485	4.576	670	4.059	855	2.718	1040	1.862
		490	4.537	675	4.020	860	2.686	1045	1.851
		495	4.600	680	3.979	865	2.655	1050	1.829
		500	4.564	685	3.936	870	2.624	1055	1.808
		505	4.570	690	3.920	875	2.592	1060	1.791
		510	4.571	695	3.875	880	2.561	1065	1.770
		515	4.424	700	3.829	885	2.529	1070	1.753
		520	4.394	705	3.783	890	2.497	1075	1.732
		525	4.522	710	3.762	895	2.385	1080	1.715
		530	4.605	715	3.715	900	2.282	1085	1.693
350	1.764	535	4.657	720	3.472	905	2.393	1090	1.677
355	1.781	540	4.686	725	3.458	910	2.282	1095	1.661
360	1.829	545	4.687	730	3.454	915	2.248	1100	1.644
365	2.086	550	4.614	735	3.477	920	2.282	1105	1.590
370	2.202	555	4.540	740	3.497	925	2.266	1110	1.452
375	2.235	560	4.488	745	3.474	930	1.650	1115	1.136
380	2.127	565	4.463	750	3.424	935	1.335	1120	0.9712
385	2.030	570	4.413	755	3.390	940	1.891	1125	0.8626
390	2.016	575	4.417	760	2.923	945	1.584	1130	1.082
395	2.199	580	4.418	765	3.213	950	1.621	1135	0.5429
400	2.873	585	4.381	770	3.287	955	1.513	1140	1.136
405	3.566	590	4.366	775	3.252	960	1.693	1145	0.9288
410	3.738	595	4.362	780	3.217	965	1.822	1150	1.095
415	3.756	600	4.334	785	3.193	970	2.022		
420	3.809	605	4.314	790	3.147	975	1.966		
425	3.801	610	4.292	795	3.112	980	1.979		
430	3.627	615	4.276	800	3.068	985	2.016		
435	3.755	620	4.283	805	3.037	990	2.036		
440	4.238	625	4.267	810	2.973	995	2.034		
445	4.539	630	4.249	815	2.781	1000	2.016		
450	4.695	635	4.231	820	2.851	1005	1.991		
455	4.720	640	4.211	825	2.864	1010	1.986		
460	4.698	645	4.187	830	2.792	1015	1.959		
465	4.718	650	4.163	835	2.787	1020	1.949		
470	4.802	655	4.160	840	2.821	1025	1.921		
475	4.908	660	4.129	845	2.791	1030	1.905		
480	4.854	665	4.094	850	2.749	1035	1.889		

Figure 2-4. Example of SCAT3 Output and Typical Spectral Array Generated by AMOS

2.3.3 Error Messages

If a parameter specified on the Data Card is out of range or a required option is omitted, an appropriate error message(s) will precede the reprint of the command card values. Figure 2-5 shows an output page that lists several possible error messages. This is not a complete list of all possible messages but it illustrates their format. A complete listing of possible error messages generated by subroutine AMOS is contained in Appendix B.

```
GENERATE SCATIII AMOS PART
          ***   ALB RF 105.00 OUT OF RANGE (0-1.)
          ***   ALB TYP   5 INVALID
          ***   LAT 100.00 INVALID
          **  SA  -6.23 DEG OUT OF RANGE (-5 TO 90)
          ***   ZEN ANGLE  185.0 OUT OF RANGE (0-90)
          **  CATS ANGLE  185.0 OUT OF RANGE (0-180)
          ***       78.0 DEG CELSIUS OUT OF RANGE (-/+50)
  *** INPUT OF DATE WRONG -- ASSUMED YOU MEANT 10/13/77
  *** PRESSURE 27.50 IN HG CONVERTED TO    931.3 MB
          ***   T550  TAVG OVERRIDES PM  2.000 &/OR  RH    0.80
                   DATE:  10/13/77

   SA    -10.0  ( -6.2)        TEMP 78.0 DEG C                    T550   0.740    TAVG
   CATS 185.0                  RH    0.60                         UZ 50.00
   ZEN  185.0                  SL PRES  931.3 MB  (  977.6)       PM  2.000 LM
   LAT  100.0                  DUST     0.0 P/ML

   ELEV  -0.500 KM             ALB TYPE 5                         KR   -0.00892
   VA   150.000                ALB REF105.00                      KA    0.0
                                                                  C      1.538
                                                                  H      0.134

          ***  UNABLE TO RUN AMOS FOR THIS CASE  ***

GENERATE SYSINT VFUN STD
          ***   AMOS ELEMENT(S) NOT LOCATED
          SD  899N              OPT  457L             REF  825F
          ***   UNABLE TO RUN SYSINT   FOR THIS CASE
   END OF INPUT - JOB COMPLETE - EXECUTION TERMINATED
```

NOTE: The improperly specified data card below was responsible for the error messages above.

```
-10. 185. 185. 78. 80. 27.5 TAVG50. 131077100. -.5          185.5      2.
```

Figure 2-5. Examples of Potential Error Messages Generated by AMOS

SECTION 3

DESCRIPTION OF COMMAND: GENERATE SYSINT VFUN

3.1 COMMAND FORMAT

A special user function SYSINT VFUN has been provided that calculates spectrally integrated ground-level irradiances, atmospheric path radiance, and effective atmospheric transmittance for a generalized system. This function is used in conjunction with an AMOS run, which must precede it, however. By overriding the default elements and the system constant, the computations can be performed for a wide variety of system components. The default elements are listed in Appendix C. Figure 1-2, items 3, 4, and 5 illustrate the input for a typical run of this function along with its associated AMOS run.

3.2 INPUTS

A *typical command is:* GENERATE SYSINT VFUN XXX YYY ZZZ. The variables XXX, YYY, and ZZZ are element names for the detector, optics, and ground reflectance, respectively. These elements can be extracted from the disk library or entered on cards via a preceding I/O READIN step. If any of these elements are defined short of the range 400 to 1100 nm, the integration limits are adjusted accordingly. The element defining the detector should be peak-normalized to the value of 1. The user can set all three elements to their default values by replacing XXX with STD and omitting YYY and ZZZ. Any single element can be set to its default value by specifying in DEF in place of the element name. This is shown in Figure 3-1. The variables, which are specified as XXX, YYY, or ZZZ use the input codes defined in the table below.

An optional units-conversion multiplier may be specified as K = F.FF. The printed values of output ERS and EH will be multiplied by F.FF. If no value is specified, 1.00 is assumed.

```
GENERATE SYSINT VFUN STD

GENERATE SYSINT VFUN DEF DEF 1Ø3R

GENERATE SYSINT VFUN F218 DEF 293R K=2.75
```

Figure 3-1. Example of Correctly Formatted SYSINT VFUN Commands

Element Names	Codes	Definition
XXX (for Detector):	STD	The code that permits all three spectral elements to assume their default values. (XXX becomes 899N, YYY becomes 457L, and ZZZ becomes 825F.)
	DEF	The code that only permits XXX to default to 899N.
	Any valid element name (i.e,835N)	A spectral array defined in the library of elements that represents the system spectral response. The values should be peak-normalized.
YYY (for Optics):	DEF	The code that only permits XXX to default to 457L.
	Any valid element name (i.e.,424L)	A spectral array defined in the library of elements representing the system spectral optical transmittance.
ZZZ (for Ground Reflector):	DEF	The code that only permits ZZZ to default to 825F.
	Any valid element name (i.e.,179RF)	A spectral array defined in the library of elements representing the spectral reflectance of a ground object.

3.3 OUTPUTS

Each use of the SYSINT VFUN Command generates one page of output. An example of this output is shown in Figure 3-2. The format for this output is summarized below.

Line(s)	Data Provided
1	Array element names for detector (SD), optics (OPT), and reflectance on the ground (REF).
2-5	The integrated effective value for the radiance (ERS) assumed reflector (REF) under the various forms of ground level irradiance and effective path transmittance (TEFF) relative to each irradiance.
6	The integrated effective atmospheric path radiance x π(EH).
7	The assumed or read-in value of K.

If one or more of the spectral elements is not defined over the range 400 to 1100 nm, the integration limits are changed. If this occurs, a warning message; e.g., UPPER INTEGRATION LIMIT LOWERED TO 1000 nm, is printed.

The two following error indications may possibly be encountered.

(1) NO AMOS ELEMENTS LOCATED . . . which indicates that the program was unable to locate elements T, SK, and DH, etc, from a prior AMOS run or from the disk library.

(2) UNABLE TO LOCATE XXX, which indicates that the spectral array element XXX was not found in the disk library or from a previous step.

3.4 SUMMARY OF COMPUTATIONS

The following equations are used in SYSINT VFUN

a. Effective Integrated Irradiances:

$$ERS = K\left[\int_{400}^{1100} H(\lambda)\cdot R_s(\lambda)\cdot T(\lambda)\cdot L(\lambda)\cdot S_D(\lambda)\,d\lambda\right]$$

```
GENERATE SYSINT VFUN STD

       SD  894N                  OPT  657L               REF  825F

       DH             ERS           27.500             TEFF         0.84712

       DV             ERS           66.136             TEFF         0.84767

       SH             ERS           2.7786             TEFF         0.82562

       SVB            ERS           6.6681             TEFF         0.85182

       EH        11.1780

       K          1.0000
```

Figure 3-2. Example of SCAT3 Output: Integrated Values Generated by SYSINT VFUN Command

b. Atmospheric Path Radiance:

$$EH = \pi \cdot K \cdot \left[\int_{400}^{1100} N_h(\lambda) \cdot L(\lambda) \cdot S_D(\lambda)\, d\lambda \right]$$

c. Effective Atmospheric Path Transmittance:

$$TEFF = \frac{\int_{400}^{1100} H(\lambda) \cdot R_S(\lambda) \cdot T(\lambda) \cdot L(\lambda) \cdot S_D(\lambda)\, d\lambda}{\int_{400}^{1100} H(\lambda) \cdot R_S(\lambda) \cdot L(\lambda) \cdot S_D(\lambda)\, d\lambda}$$

In the above equations, the integrand variables are defined as follows:

$T(\lambda)$ is the spectral atmospheric path transmittance (AMOS array name is T).

$N_h(\lambda)$ is the spectral atmospheric path radiance in watts/m^2/5 nm steradian (AMOS array name is SK).

$H(\lambda)$ is either skylight or daylight irradiance on either a horizontal or a vertical surface in watts/m^2/5 nm (AMOS array names are DH, DV, SH, SVB).

In addition, the integrand variables from the disk library or a preceding I/O READIN step are defined as follows:

$S_D(\lambda)$ is the spectral sensitivity of the Film/Detector (peak-normalized)

$L(\lambda)$ is the spectral transmittance of the optics, and

$R_S(\lambda)$ is the spectral ground reflectance.

SECTION 4

DESCRIPTION OF COMMAND I/O READIN

4.1 GENERAL DESCRIPTION

This command is used to read any element array into the program for use in computations or for permanent storage in the disk library. The general form of the command is:

I/O READIN (option)

The possible options are:

NOLIST which allows the spectral array to be read into a temporary file, but returns no printed listing of the array.

SAVE which allows the spectral array to be read in and stored as a permanent array by the element name given on the header card (equivalent to a FILE SAVE Command, see section 5), or,

"Blank" which allows the spectral array to be read into a temporary file and results in a printed listing of the array.

Any element of the same name that is already in the library is printed out and replaced. The response SAVED ON DISK indicates satisfactory completion. Following the command card are a header card and data cards that contain the spectral values.

4.2 INPUTS

Once the I/O READIN command has been specified, a number of spectral arrays can be read in. Each array, or element, is read in using a header card and a series of data cards in the formats described below.

HEADER CARDS

Column	Format	Description
1-8	A8	Name of element in 4 to 8 alphanumeric characters, at least one of which must be alphabetic.
10-12	A3	One of the following four transformations must be used to indicate condition of the data. VAL: In correct form LOG: In logarithmic form LIN: In log-inverse form INV: In inverse form
20-22	I3	The wavelength of first data point.
29-32	I4 (right justified)	The wavelength of last data point.
40-49	F10.4	The constant that is multiplied times every data point <u>after</u> conversion to the correct form. If left blank, default is 1.0.
73-80	A8 (right justified)	The date when the deck was made. It must always be present and never use less than columns 75-80 (ex: 1/1/78).

DATA CARDS

Column	Format	Description
1-70	10E7.2	Lists spectral data starting with the value for the first wavelength specified on the header card and continuing on other cards until the value for the last wavelength has been reached.
73-76	A4	Identification.
79-80	I2 (right justified)	The order number of the card.

SECTION 5

DESCRIPTION OF THE COMMAND FILE

5.1 GENERAL DESCRIPTION

This command is used to maintain the disk library of elements. Each card must contain one complete command to store or delete a spectral array on the disk file.

The first card must contain the word FILE beginning in column 1. The cards immediately following the first card need not contain the word FILE, but instead can be blank in column 1. Each command item (SAVE, DELETE, NAME, etc) must be separated from the next item at least one blank. Blanks must not be used within a command word.

The name by which an array is to be saved in a disk file may contain (1) as many as eight characters and (2) any combination of letters and numerals. However, all numerals cannot be used.

5.2 INPUTS

Three possible FILE commands can be given, each of which must be structured as indicated in paragraph 5.1 above.

5.2.1 FILE SAVE XXX BY YYY

> (In the following paragraphs, XXX refers to the name of an array that is either to be stored by the new name YYY or deleted; XXX and YYY can be identical.)

This command performs the basic task of placing XXX in the disk file and giving it the element name YYY. If another array is already on the disk by the second name, the save operation will not be executed. Instead, both arrays will be printed.

5.2.2 FILE SAVE XXX BY YYY U

This command differs only from that of 5.2.1 in that it replaces existing elements in the disk file (e.g., with an improved estimate of the same lens transmittance). After the array XXX is stored by the name YYY, both the old element YYY and the new element YYY will be printed.

5.2.3 FILE DELETE XXX

The purpose of this command is to erase the specific element XXX from the disk file. After the array is deleted, the element XXX is printed to indicate what has been erased.

SECTION 6

OTHER FUNCTIONS

6.1 GENERAL DESCRIPTION

In addition to the commands already discussed, SCAT3 also supports several other command functions that are occasionally used. These commands are given on a single card, and they usually generate one page of output. The element that is created by these commands is often used in subsequent steps. Two of these functions are discussed below.

6.2 I/O FUNCTIONS

In addition to the I/O READIN function discussed in Section 4 of this report, function I/O PRINT and I/O DUMP are also available. The first of these, I/O PRINT, is used to print an element array or constant. For this item, the command is I/O PRINT XXX YYY ZZZ . . . where XXX, YYY, etc, are the names of elements in the program, or in the disk library. The user may specify as many element names as will fit on the command card, but each name must be separated by blanks. An example of the output format for any array element is shown in Appendix C.

The command I/O DUMP is used by the programmer who maintains the disk library; it can also be used in debugging problems within the program. The command I/O DUMP will generate listings of the names of all elements in the disk library, and those in the program's core data table (CDT).

6.3 GENERATE FUNCTION

In addition to the command GENERATE SYSINT VFUN described in Section 3 of this report, there are several other GENERATE functions. The resulting output is printed in the format shown in Appendix C for an array element, or one value per page for a constant. The inputs for these functions are of two types: single operator functions and double operand computations.

6.3.1 Single Operator Functions

These commands are of the form: GENERATE XXX = (function) YYY, where the function can be any of those described below.

(1) SUM. Integrates the values of an array element over its spectral range. The output is a constant.

Example: GENERATE X = SUM XYZ where XYZ is an array element and X will be the integral constant.

(2) LOG. Takes the log (base 10) of a constant or of each value of an array.

Example: GENERATE LOGX = LOG X.

(3) AREA NORMALIZE. Creates a scaled array such that the area under the curve is equal to 1.0, and the shape is the same as the input array.

Example: GENERATE ANX = AREANORMALIZE X, where X is a spectral array.

(4) PEAK NORMALIZE. Creates a scaled array such that the maximum value is 1.0, and the shape is the same as the input array.

Example: GENERATE PKK = PEAKNORMALIZE X, where X is a spectral array.

(5) BBODY. Generates an array element from 300-1200 nm for a black body radiator at the given color temperature (°K).

Example: GENERATE BB BBODY 3200.
Note: No equals sign (=) is used.

(6) BANDPASS. Generates an array element from 300-1200 nm for a band-pass filter. At wavelengths from LOW to HIGH, the element has values of 1. Elsewhere it has values of zero.

Example: GENERATE FILT BANDPASS (450) (1025) where low is 450 nm and HIGH is 1025 nm.

(7) User Function. Program SPECTR provides for three user-written functions to give access to program elements and utility routines.

The user function is a FORTRAN program with the name SUBROUTINE UFUNCT (, ,). As with other functions in the program SPECTR, the user function must be called by an appropriate command of the form:

GENERATE XXX* CFUN (option, option, . . .)

SCAT 3, for example, uses a user function** routinely to perform spectral integrations of arrays generated by AMOS. Within the constraints of subroutine name and command, complete flexibility is contained in this user option. Appendix E reviews, in more detail, the generation of a user function routine which can be used as a guide in development of new ones. Reference to the SCAT3 program listings must be made before one attempts to write a user function.

6.3.2 Double Operand Functions

The GENERATE Command also provides for double operand computations such as addition, subtraction, multiplication, division, and exponentiation. The user may perform the above computations on constant elements, array elements, or numeric values. However,an array cannot be raised to an array power or divided by zero.

Examples of the above computations are:

```
GENERATE A = B + C
         X = Y * A
         Y = M * X
         Y = Y + B
        PI = 3.14159 x 1
   ANTILOG = 10. ** A
```

The word GENERATE may be omitted after the first GENERATE command if the subsequent commands do not begin in column 1.

---

* A user-provided variable name that is subject to the restrictions discussed in Section 4.2.1, Element Name.

** See Section 3 of this report.

APPENDIX A

SCAT3 TEST CASES

A series of 15 test cases was constructed and run to utilize all possible input options and variables and to illustrate the output of a correctly assembled input deck. Figure A-1 is an annotated copy of the input commands that were used, and Table A-1 lists the respective 15 output results.

Figure A-1. Input Data for SCAT3 Test Cases

LISTING OF INPUT RECORDS

RECORD NUMBER	CASE	RECORD	4/12/78 COMMENTS
1		GENERATE SCAT3 AMOS FULL	
2	1	40. TAVG 5 67839. 10000.	
3		GENERATE SYSINT VFUN STD	
4		GENERATE SCAT3 AMOS PART	
5	2	10.0 50.0 70.0 .2 2.7 4 178	
6		GENERATE SYSINT VFUN STD	
7		GENERATE SCAT3 AMOS PART	
8	3	40.0 .2 2.7 4 178	
9		GENERATE SYSINT VFUN STD	
10		GENERATE SCAT3 AMOS PART	
11	4	45.0 45.0 0.0 TAVG2.7 4 178	Away from sun
12		GENERATE SYSINT VFUN STD	
13		GENERATE SCAT3 AMOS PART	
14	5	40.0 30.0 80.0 TAVG2.7 4 178	Into the sun
15		GENERATE SYSINT VFUN STD	
16		GENERATE SCAT3 AMOS PART	
17	6	40.0 TAVG 4 17840. 1.524	5000 ft station elevation
18		GENERATE SYSINT VFUN STD	
19		GENERATE SCAT3 AMOS PART	
20	7	40.0 RAYL 4 17840. 1	Rayleigh atmosphere/desert
21		GENERATE SYSINT VFUN STD	
22		GENERATE SCAT3 AMOS PART	
23	8	40.0 0.0 0.0 32. .10 1028.0 4 17840. 1.524 0.000 1	Surface weather input
24		GENERATE SYSINT VFUN STD	
25		GENERATE SCAT3 AMOS PART	Snow surround day in Alaska;
26	9	12. -20..4 999.0 12247854.4 0.5 .5 2	non-standard scene
27		GENERATE SYSINT VFUN DEF DEF 173RF K=.983	
28		GENERATE SCAT3 AMOS PART	
29	10	40. 15. .4 2.9 12247842. 0.250 3	
30		GENERATE SYSINT VFUN STD	
31		GENERATE SCAT3 AMOS PART	
32	11	40.0 30.0 20.0 15. .4 4 17842. 4	Away from sun
33		GENERATE SYSINT VFUN STD	
34		GENERATE SCAT3 AMOS PART	
35	12	40.0 60.0110.0 15. .5 4 17842. 4	Into the sun
36		GENERATE SYSINT VFUN STD	
37		GENERATE SCAT3 AMOS PART	
38	13	40.0 4 17842. 3.8	Precipitable moisture
39		GENERATE SYSINT VFUN STD	
40		GENERATE SCAT3 AMOS PART	
41	14	70.0 RAYL 4 17842.	
42		GENERATE SYSINT VFUN STD	
43		GENERATE SCATIII AMOS PART	
44	15	-10. 185. 185. 78. 80. 27.5 TAVG50. 131077100. -.5 105.5 2.	Errors!!
45		GENERATE SYSINT VFUN STD	

END OF INPUT RECORDS

TABLE A-1

INTEGRAL RESULTS FOR SCAT3 TEST CASES
(K=1.0)

	INPUT PARAMETERS					OUTPUTS			
Case No.	SA	ZEN	CATS	Albedo Type	Atmospheric Estimate	ERS/DH	ERS/DV	EH	TEFF/DH
1*	40	0	50	Urban/Industrial	Average	30.36	42.17	8.89	.856
2	10	50	70	Urban/Industrial	T550 = .2	.37	.52	18.91	.0898
3	40	0	50	Urban/Industrial	T550 = .2	4.46	5.69	70.67	.204
4	45	45	0	Urban/Industrial	Average	27.04	32.56	30.33	.722
5	40	30	80	Urban/Industrial	Average	25.76	35.67	18.43	.766
6	40	0	50	Urban/Industrial	Average	27.32	37.82	13.57	.804
7	40	0	50	Desert	Rayleigh	35.67	53.92	6.68	.929
8	40	0	50	Desert	Weather	32.80	48.77	9.96	.885
9**	12	0	78	Snow	Weather	54.33	220.96	8.19	.866
10	40	0	50	Forest	Weather	32.53	47.29	11.52	.870
11	40	30	20	Urban/Industrial	Weather	30.03	42.23	16.75	.845
12	40	60	110	Urban/Industrial	Weather	26.60	37.37	23.32	.748
13	40	0	50	Urban/Industrial	Precipitable Moisture	17.88	23.48	27.09	.598
14	70	0	20	Urban/Industrial	Rayleigh	52.59	25.39	8.79	.928
15	(Invalid run to illustrate error messages.)								

* 10,000 ft. altitude.

** Snow surround case with K = 0.983.

APPENDIX B

ERROR MESSAGES THAT MIGHT BE GENERATED BY SCAT3

The meaning of each of the following error messages is explained on the line below the message.

1. ALB RF XX.XX OUT RANGE (0-1)

   Albedo surround reflectance value XX.XX not between 0 and 1.

2. ALB TYPE N INVALID

   Albedo surround type N not valid (0-4).

3. YOU MUST SPECIFY A TYP AS WELL AS AN ALB REF

   If you override the default albedo surround reflectance you must specify TYP 1-4.

4. AN ELEVATION OF XX.X KM SEEMS TOO HIGH

   Warning.

5. YOU ARE UNDERGROUND XX.XX KM

   A negative observer altitude.

6. LAT XX.XX INVALID

   Latitude must be -90 to +90. For southern hemisphere (negative latitude) an ozone value of 3.0mm is assumed.

7. SA XX.X DEG OUT OF RANGE (-5 -90)

   The solar altitude, after any low solar altitude refraction correction, exceeds the range of the model.

8. RH XX.XX OUT OF RANGE (0 - 1.00)

   Relative humidity out of range.

9. ZEN ANGLE XX.XX OUT OF RANGE (0 - 90)

   Observation angle not between 0 and 90 degrees.

10. CATS ANGLE XX.X OUT OF RANGE (0 - 180)

11. XX.X DEG CELSIUS OUT OF RANGE (-/+50)

    Temperature out of range.

12. SPECIFYING PM X.XXX OVERRIDES RH XXX

    Warning.

13. YOU MUST SPECIFY EITHER RH, PM, or T550.

APPENDIX B (Con't)

14. YOU SPECIFIED BOTH A RAYLEIGH ATMOSPHERE & A PM OF X.XXX

15. YOU SPECIFIED BOTH A RAYLEIGH ATMOSPHERE & A RH OF X.XXX

16. T550 NNNN OVERRIDES PM XXX &/OR RH X.XX

    Warning.

17. T550 X.XXX OUT OF RANGE (.2 - .815)

18. READ/FORMAT ERROR IN AMOS INPUT CARD

    Error return from FORTRAN READ (. . .

19. ANGLE IN BEMAS X.XX GT 90 DEGREES

    Warning, which may occur with negative solar altitude.

20. CONVERTED X.XX FT TO Y.YY KM

    Advisory.

21. NO INPUT DATE -- ASSUMED TODAY -/-/-

    Advisory.

22. INPUT DATE WRONG - ASSUMED YOU MEANT -/-/-

    Warning when day and month interchanged.

23. DATE -/-/- NOT USABLE

24. CREARH -VE PM ... PM, KA, KO3, TS ....

    Combination of T550, ozone, pressure, temperature, dust etc, give a negative value for calculated precipitable moisture. This error would be followed by a system "log of negative number" error.

25. RH X.XX & TEMP YY.Y DEG C NOT CONSISTENT WITH T550 Z.Z IN CREARH

    Calculated a relative humidity over 100%.

26. DEFAULT TEMPERATURE INCREASED TO XX.X DEG C

    Advisory.

27. DO YOU REALLY WANT OZONE AT THE EQUATOR?

    Advisory when no OZ specified and LAT is zero.

28. PRESSURE XX.XX IN HG CONVERTED TO YY.Y MB

    Advisory when units converted from inches of mercury to millibars.

29. PRESSURE X.XX MB OUT OF RANGE (500 - 1200)

30. AMOS ELEMENT(S) NOT LOCATED

Run of SYSINT VFUN could not locate required elements from an AMOS run.

31. UNABLE TO RUN SYSINT FOR THIS CASE

Run of SYSINT VFUN could not locate elements specified for detector, optics, etc.

32. UPPER (LOWER) INTEGRATION LIMIT LOWERED (RAISED) TO NNN NM

Run of SYSINT VFUN adjusted integration limits from 400-1100 nanometers to conform to range of one or more of the specified elements.

In addition to these messages from the AMOS package, many error messages may be generated by the SPECTR package, particularly if the user generates his own user function, or does spectral computations (e.g., GENERATE X = DH * .4. These messages are generally self-explanatory.

Other error messages such as "JCL ERROR" or "INSUFFICIENT CORE" may be generated by the computer operating system, and will depend upon the installation.

APPENDIX C

SYSINT VFUN DEFAULT ELEMENTS

The tables of spectral data default elements shown in Tables C-1 through C-3 are called in SYSINT VFUN when no specific elements have been named in the command. The default value of the system constant is 1.0. These spectral data also illustrate the I/O PRINT XXX command discussed in Section 6 of this report.

TABLE C-1

DEFAULT SPECTRAL ARRAY FOR THE DETECTOR (PEAK NORMALIZED)

VALUES FOR 899N

400	0.5492
405	0.5508
410	0.5588
415	0.5668
420	0.5749
425	0.5829
430	0.5910
435	0.5997
440	0.6086
445	0.6178
450	0.6269
455	0.6352
460	0.6433
465	0.6521
470	0.6611
475	0.6717
480	0.6827
485	0.6930
490	0.7031
495	0.7148
500	0.7271
505	0.7392
510	0.7512
515	0.7633
520	0.7754
525	0.7889
530	0.8027
535	0.8170
540	0.8315
545	0.8419
550	0.8519
555	0.8611
560	0.8701
565	0.8773
570	0.8844
575	0.8900
580	0.8955
585	0.9018
590	0.9085
595	0.9137
600	0.9187
605	0.9247
610	0.9307
615	0.9358
620	0.9409
625	0.9441
630	0.9472
635	0.9510
640	0.9551
645	0.9582
650	0.9612
655	0.9642
660	0.9673
665	0.9703
670	0.9733
675	0.9763
680	0.9793
685	0.9815
690	0.9835
695	0.9855
700	0.9875
705	0.9895
710	0.9915
715	0.9936
720	0.9956
725	0.9978
730	1.000
735	0.9995
740	0.9990
745	0.9985
750	0.9980
755	0.9947
760	0.9907
765	0.9855
770	0.9799
775	0.9719
780	0.9638
785	0.9558
790	0.9477
795	0.9377
800	0.9277
805	0.9176
810	0.9076
815	0.8960
820	0.8839
825	0.8703
830	0.8563
835	0.8419
840	0.8273
845	0.8123
850	0.7972
855	0.7812
860	0.7651
865	0.7481
870	0.7310
875	0.7120
880	0.6929
885	0.6720
890	0.6509
895	0.6276
900	0.6029
905	0.5806
910	0.5585
915	0.5321
920	0.5059
925	0.4849
930	0.4638
935	0.4436
940	0.4236
945	0.4045
950	0.3854
955	0.3653
960	0.3453
965	0.3272
970	0.3094
975	0.2943
980	0.2793
985	0.2652
990	0.2511
995	0.2360
1000	0.2211
1005	0.2090
1010	0.1968
1015	0.1823
1020	0.1691
1025	0.1600
1030	0.1508
1035	0.1407
1040	0.1307
1045	0.1217
1050	0.1127
1055	0.1046
1060	0.9657E-01
1065	0.8763E-01
1070	0.7945E-01
1075	0.7397E-01
1080	0.6848E-01
1085	0.6245E-01
1090	0.5642E-01
1095	0.5139E-01
1100	0.4637E-01

TABLE C-2

DEFAULT SPECTRAL ARRAY FOR LENS TRANSMITTANCE

VALUES FOR 457L

		485	0.8050	670	0.8110	855	0.8000	1040	0.7820
		490	0.8100	675	0.8080	860	0.8000	1045	0.7810
		495	0.8150	680	0.8050	865	0.8000	1050	0.7800
		500	0.8200	685	0.8020	870	0.8000	1055	0.7780
		505	0.8210	690	0.7990	875	0.8000	1060	0.7760
		510	0.8220	695	0.7970	880	0.8000	1065	0.7740
		515	0.8230	700	0.7950	885	0.8000	1070	0.7720
		520	0.8240	705	0.7940	890	0.8000	1075	0.7700
		525	0.8250	710	0.7930	895	0.8000	1080	0.7680
		530	0.8250	715	0.7920	900	0.8000	1085	0.7660
		535	0.8250	720	0.7910	905	0.8000	1090	0.7640
		540	0.8250	725	0.7910	910	0.8000	1095	0.7620
		545	0.8250	730	0.7910	915	0.8000	1100	0.7600
		550	0.8250	735	0.7920	920	0.8000		
		555	0.8250	740	0.7930	925	0.8000		
		560	0.8250	745	0.7940	930	0.8000		
		565	0.8250	750	0.7950	935	0.8000		
		570	0.8250	755	0.7950	940	0.8000		
		575	0.8250	760	0.7960	945	0.8000		
		580	0.8250	765	0.7960	950	0.8000		
400	0.3200	585	0.8250	770	0.7970	955	0.7990		
405	0.4500	590	0.8250	775	0.7980	960	0.7980		
410	0.5200	595	0.8250	780	0.7980	965	0.7970		
415	0.5700	600	0.8250	785	0.7990	970	0.7960		
420	0.6100	605	0.8250	790	0.7990	975	0.7950		
425	0.6400	610	0.8250	795	0.8000	980	0.7940		
430	0.6700	615	0.8250	800	0.8000	985	0.7930		
435	0.6900	620	0.8250	805	0.8000	990	0.7920		
440	0.7200	625	0.8250	810	0.8000	995	0.7910		
445	0.7350	630	0.8240	815	0.8000	1000	0.7900		
450	0.7500	635	0.8230	820	0.8000	1005	0.7890		
455	0.7600	640	0.8220	825	0.8000	1010	0.7880		
460	0.7700	645	0.8210	830	0.8000	1015	0.7870		
465	0.7800	650	0.8200	835	0.8000	1020	0.7860		
470	0.7880	655	0.8190	840	0.8000	1025	0.7850		
475	0.7950	660	0.8170	845	0.8000	1030	0.7840		
480	0.8000	665	0.8140	850	0.8000	1035	0.7830		

TABLE C-3

DEFAULT SPECTRAL ARRAY FOR STANDARD GROUND REFLECTOR

VALUES FOR 825F

		485	0.8980E-01	670	0.1272	855	0.1469	1040	0.1666
		490	0.9080E-01	675	0.1277	860	0.1474	1045	0.1672
		495	0.9190E-01	680	0.1282	865	0.1480	1050	0.1677
		500	0.9300E-01	685	0.1288	870	0.1485	1055	0.1682
		505	0.9400E-01	690	0.1293	875	0.1490	1060	0.1688
		510	0.9510E-01	695	0.1298	880	0.1496	1065	0.1693
		515	0.9610E-01	700	0.1304	885	0.1501	1070	0.1698
		520	0.9720E-01	705	0.1309	890	0.1506	1075	0.1704
		525	0.9830E-01	710	0.1314	895	0.1512	1080	0.1709
		530	0.9930E-01	715	0.1320	900	0.1517	1085	0.1714
350	0.6100E-01	535	0.1004	720	0.1325	905	0.1522	1090	0.1720
355	0.6200E-01	540	0.1015	725	0.1330	910	0.1528	1095	0.1725
360	0.6310E-01	545	0.1025	730	0.1336	915	0.1533	1100	0.1730
365	0.6420E-01	550	0.1036	735	0.1341	920	0.1538	1105	0.1736
370	0.6520E-01	555	0.1047	740	0.1346	925	0.1544	1110	0.1741
375	0.6630E-01	560	0.1057	745	0.1352	930	0.1549	1115	0.1746
380	0.6740E-01	565	0.1068	750	0.1357	935	0.1554	1120	0.1752
385	0.6840E-01	570	0.1079	755	0.1362	940	0.1560	1125	0.1757
390	0.6950E-01	575	0.1089	760	0.1368	945	0.1565	1130	0.1762
395	0.7060E-01	580	0.1100	765	0.1373	950	0.1570	1135	0.1768
400	0.7160E-01	585	0.1111	770	0.1378	955	0.1576	1140	0.1773
405	0.7270E-01	590	0.1121	775	0.1384	960	0.1581	1145	0.1778
410	0.7380E-01	595	0.1132	780	0.1389	965	0.1586	1150	0.1784
415	0.7480E-01	600	0.1143	785	0.1394	970	0.1592	1155	0.1789
420	0.7590E-01	605	0.1153	790	0.1400	975	0.1597	1160	0.1794
425	0.7700E-01	610	0.1164	795	0.1405	980	0.1602	1165	0.1800
430	0.7800E-01	615	0.1175	800	0.1410	985	0.1608	1170	0.1805
435	0.7910E-01	620	0.1185	805	0.1416	990	0.1613	1175	0.1810
440	0.8020E-01	625	0.1196	810	0.1421	995	0.1618	1180	0.1816
445	0.8120E-01	630	0.1207	815	0.1426	1000	0.1624	1185	0.1821
450	0.8230E-01	635	0.1217	820	0.1432	1005	0.1629	1190	0.1826
455	0.8340E-01	640	0.1228	825	0.1437	1010	0.1634	1195	0.1832
460	0.8440E-01	645	0.1239	830	0.1442	1015	0.1640	1200	0.1837
465	0.8550E-01	650	0.1250	835	0.1448	1020	0.1645		
470	0.8660E-01	655	0.1256	840	0.1453	1025	0.1650		
475	0.8670E-01	660	0.1261	845	0.1458	1030	0.1656		
480	0.8870E-01	665	0.1266	850	0.1464	1035	0.1661		

APPENDIX D

PROGRAMMER'S AIDS

This appendix contains guidelines for the programmer who will maintain SCAT3. The call hierarchy of SCAT3 subroutines is shown in Figure D-1, subroutine definitions are contained in Figure D-2; and the JCL to run program SCAT3 is shown in Figure D-3.

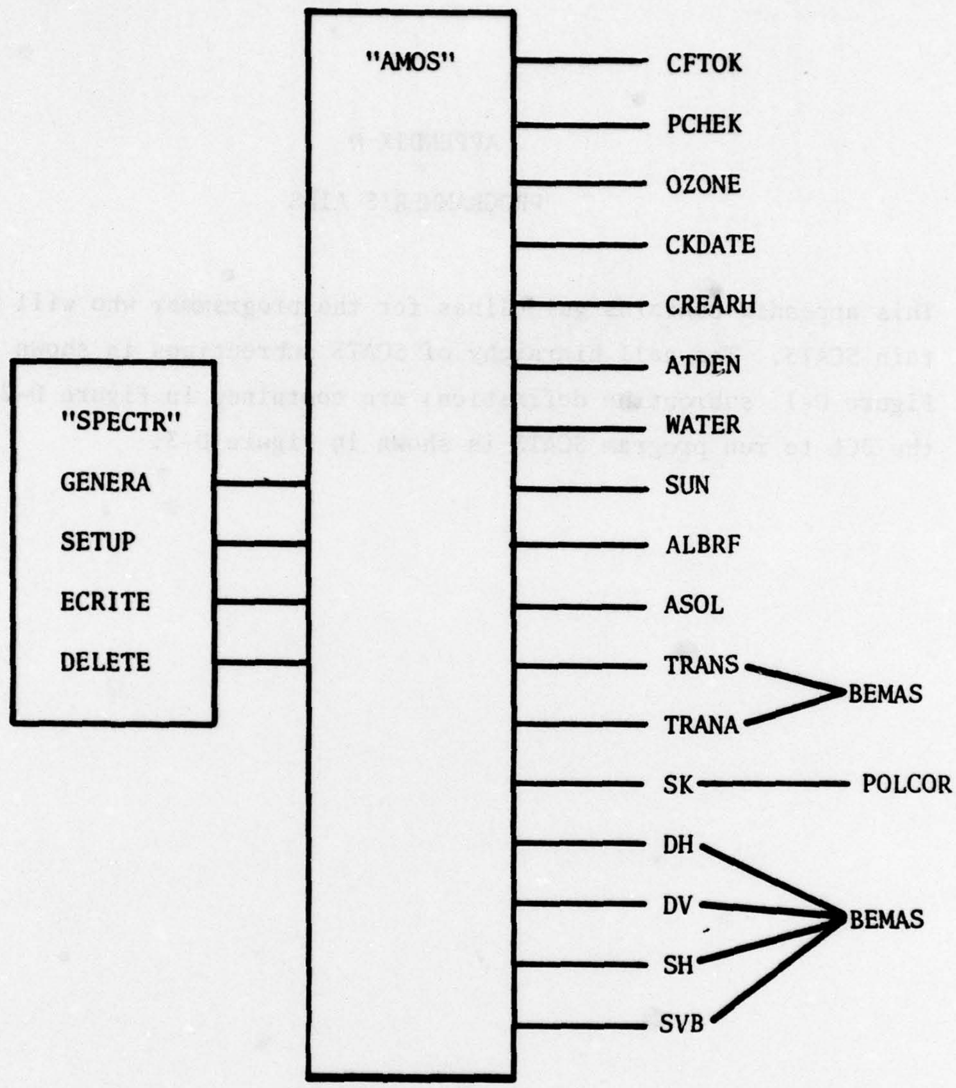

Figure D-1. Call Hierarchy of SCAT3 Subroutines

Figure D-2. Program Notes

SCAT3 is a generalized program for manipulating spectral elements, and generating optical characteristics of the atmosphere.

```
            SUBROUTINES
            ***********

A.  ATMOSPHERIC PACKAGE:

    AMOS     "MAINLINE"..INTERFACE WITH SPECTR. DECODES DATA CARD
             CHECKS &/OR SETS UP CONSTANTS & DEFAULTS.  SETS
             UP TEMPORARY ELEMENTS IN CORE DATA TABLE.

    ALBRF    GENERATES APPROPRIATE ALBEDO SPECTRAL REFLECTANCE

    ASOL     CALCULATES AEROSOL SCATTERING PARAMETERS (KA,C)

    ATDEN    DETERMINES RAYLEIGH SCATTERING COEFFICIENT (KR)

    BEMAS    AIR MASS PATH LENGTH CORRECTION (SECANT THETA)
               BLOCK DATA AIRMAS

    CFTOK    CONVERT FEET TO KILOMETERS

    CKDATE   CHECKS INPUT DATA FOR DATE

    CREARH   CALCULATES PRECIPTIBLE MOISTURE & RH WHEN
             T550 IS SPECIFIED.  MAY INCREASE DEFAULT TEMP

    DH       GENERATES SPECTRAL ELEMENT FOR DAYLIGHT IRRADIANCE
             ON A HORIZONTAL SURFACE

    DV       GENERATES SPECTRAL ELEMENT FOR DAYLIGHT IRRADIANCE
             ON A VERTICAL SURFACE

    OZONE    ESTIMATE OF OZONE BASED ON DATE & LATITUDE
               BLOCK DATA OZTABL

    PCHEK    CHECKS INPUT PRESSURE & CORRECTS FOR ELEVATION

    POLCOP   COMPUTES ANGULAR SCATTER FUNCTION ("FISH")

    SH       GENERATES SPECTRAL ELEMENT FOR SKYLIGHT
             IRRADIANCE ON A HORIZONTAL SURFACE
```

Figure D-2 (Continued)

```
SK       GENERATES SPECTRAL ELEMENT FOR SKYLIGHT RADIANCE (HAZE)

SVB      GENERATES SPECTRAL ELEMENT FOR SKYLIGHT IRRADIANCE
         ON A VERTICAL BACKLIT SURFACE (SHADOW)

SUN      GENERATES SPECTRAL IRRADIANCE OF SUN (ABOVE ATMOSPHERE)

TRANA    CALCULATES SPECTRAL ABSORPTIONS OF WATER, OZONE & OXYGEN

TRANS    COMPUTES SPECTRAL TRANSMITTANCE DUE TO SCATTERING

WATER    CALCULATES PRECIPTIBLE MOISTURE ( MOISTURE SCALE HEIGHT)

VFUNCT   USER FUNCTION WHICH PERFORMS "SYSINT VFUN"
           SYSTEM INTEGRATIONS


B. FROM SPECTR:

MAIN     PROGRAM MAINLINE..TRANSFERS INPUT COMMAND AND
         DATA CARDS FROM //FT05 FILE TO //FT02 FILE.
         "OPENS" DISK LIBRARY FILE //FT09 AND READS DIRECTORY
         DECODES COMMANDS AND DIRECTS EXECUTION TO THE
         PROPER SUBROUTINE.

GENERA   DECODES & PROCESSES GENERATE COMMAND

IORO     DECODES & PROCESSES I/O COMMAND

FILE     DECODES & PROCESSES FILE COMMANDS

NOTE:  AMOS and GENERATE SCAT3 AMOS COMMANDS ARE DIRECTED
       TO SUBROUTINE AMOS

SETUP    ENTERS AN ELEMENT NAME IN THE CORE DATA TABLE

LOCATE   LOGICAL FUNCTION TO SEARCH FOR AN ELEMENT NAME
         IN THE CORE DATA TABLE, OR IN THE DISK LIBRARY.

DELETE   REMOVES AN ELEMENT NAME FROM THE CORE DATA TABLE,
         BUT NOT FROM THE DISK LIBRARY.

ECRITE   WRITES AN ELEMENT, ARRAY OR CONSTANT, ON THE
         LINE PRINTER.

     THERE ARE NUMEROUS OTHER SUBROUTINES IN SPECTR WHICH
      SUPPORT THOSE ALREADY MENTIONED.  CONSULT THE PROGRAM

      LISTINGS FOR DETAILS.

END
```

Figure D-3. JCL to Run Program SCAT3

```
C
//*
//*
//*
//STEPONE EXEC FORTHC,PARM.FORT='MAP,XREF,OPT=2'
//FORT.SYSIN DD *    FORTRAN SOURCE DECKS FOLLOW THIS CARD
//FORT.SYSUT2 DD UNIT=SYSDA,SPACE=(CYL,20,RLSE)
/*
//STEPTWO EXEC ASMFC,PARM.ASM='LIST,LOAD'
//ASM.SYSGO DD DSN=*.STEPONE.FORT.SYSLIN,DISP=(MOD,PASS,DELETE)
//ASM.SYSIN DD *     ASSEMBLER SOURCE FOR "CORE" FOLLOWS THIS CARD
/*
//STEP3    EXEC ASMFC,PARM.ASM='LIST,LOAD'
//ASM.SYSGO DD DSN=*.STEPONE.FORT.SYSLIN,DISP=(MOD,PASS,DELETE)
//ASM.SYSIN DD *     ASSEMBLER SOURCE FOR "DATE" FOLLOWS THIS CARD
/*
//STEPFOUR EXEC FORTHLG,PARM.LKED=(XREF,LIST,LET)
//LKED.SYSLIN DD DSN=*.STEPONE.FORT.SYSLIN,DISP=(OLD,DELETE,DELETE)
//          DD *  LINK-EDIT INPUT FOLLOWS THIS CARD
     ENTRY MAIN
/*
//GO.FT02F001 DD UNIT=SYSDA,SPACE=(CYL,(10,1)),
//   DCB=(RECFM=FB,LRECL=80,BLKSIZE=3600)
//GO.FT09F001 DD DSN=SPECTRAL.DATA,UNIT=DISK,VOL=SER=ABF225,DISP=OLD
//GO.FT10F001 DD UNIT=SYSDA,SPACE=(732,(450,1))
//GO.SYSIN DD *      INPUT DATA CARDS FOLLOW THIS CARD
/*
ALL JCL CONVENTIONS ARE FOR THIS INSTALLATION'S IBM 370, RUNNING
UNDER OS, USING THE LASP OPTION.
PLEASE NOTE THE FOLLOWING.....
/*SETUP...
     THIS CARD MAY BE REQUIRED FOR OPERATOR MOUNTING OF THE VOLUME
     IN THE 'ID' PARAMTER, WHICH IS A DISK PACK ON WHICH
     RESIDES THE SPECTRAL DATA LIBRARY (SEE FT09F001 OF THE 'GO'
     STEP)
//STEPONE...
     SEVERAL OF THE FORTRAN ROUTINES TAKE ADVANTAGE OF THE POWER
     OF THE IBM 'H' LEVEL COMPILER, AND WILL NOT COMPILE UNDER
     A LOWER LEVEL, WITHOUT MODIFACTION.  THE COMPILER OPTIONS
     STATED IN THE 'PARM' FIELD ARE HIGHLY RECOMMENDED.
     THIS JCL IS REQUIRED FOR OUR CATALOGUED PROCEDURE INVOKING THE
     'H' COMPILER.
//STEPTWO...
     THIS IS OUR CATALOGUED PROCEDURE TO INVOKE THE 'IEUASM'
     LANGUAGE COMPILER.  NOTE THE ADDITION OF THE PROCESSOR'S OUTPUT
     TO THAT ALREADY PRODUCED BY THE FORTRAN COMPILER.
//STEP3....
     SAME AS EXPLAINED FOR STEPTWO (ABOVE)
//STEPFOUR....
     THIS IS OUR CATALOGUED PROCEDURE TO INVOKE THE PROGRAM ' EWL'
```

Figure D-3 (Continued)

```
     (IBM LINKAGE EDITOR).  DEPENDING UPON THE PARTICULAR SYSTEM
     BEING USED, AN OVERLAY STRUCTURE MAY BE ADVISABLE TO CUT

     DOWN THE MEMORY REQUIREMENTS.  HOWEVER, IF THE PROGRAM CAN BE
     EXECUTED AS A SINGLE SEGMENT, RUN TIME WILL BE OPTIMIZED.
//GO.FT02F001...
     TEMPORARY DATA SET, NO NEED TO ALLOCATE PERMANENT SPACE FOR
     IT.  THIS SET-UP SPECIFIES THAT THE DATA SET IS NEW, AND WILL
     BE SCRATCHED AFTER THIS RUN.
//GO.FT09F001....
     THIS IS THE SPECTRAL DATA LIBRARY, WHICH WE HAVE SET UP ON
     A 3330 DISK PACK, VOLUME SERIAL NUMBER ABF225
     THIS PARTICULAR SETUP ASSUMES THAT THE DATA SET HAS BEEN PRE-FORMATTED
     ON THE DEVICE, WITH A SPACE PARAMETER OF (740,2920).
     THE PRE-FORMATTING COULD HAVE BEEN DONE BY A PREVIOUS RUN,
     WITH DISP=NEW, OR WITH 'IEHPROGM' UTILITY PROGRAM.
//GO.FT10F001....
     THIS IS ANOTHER SCRATCH DATA SET USED BY THE PROGRAM.


     SINCE THE PROGRAM IS QUITE LARGE, IT IS HIGHLY ADVISED THAT
     A LOAD MODULE BE CREATED, AND RETAINED IN A PRIVATE LIBRARY,
     AS SOON AS POSSIBLE.
     NOTE THE COMMENTS IN THE FORTRAN MAINLINE, REGARDING INITIAL
     USE OF THE SPECTRAL ELEMENT LIBRARY ( PRECEEDING THE CALL TO
     'FDTINT').
     THIS PROGRAM SHOULD RUN ON ANY INSTALLATION SUPPORTING
     IBM OS/360-370, ASSUMING ENOUGH MAIN STORAGE, HAVING SUITABLE
     RANDOM-ACCESS STORAGE FOR THE DATA LIBRARY, WITHOUT ANY SOURCE
     MODIFICATION.  THE JCL CAN EASILY BE MODIFIED TO ACCOMODATE ANY
     VERSION OF ASP, OR A SYSTEM RUNNING WITHOUT THE BENEFIT OF ASP.
C
```

APPENDIX E
USER WRITTEN FUNCTIONS

The user may wish to write special functions to perform repetitive calculations on elements generated by SCAT3, or provide outputs tailored to a particular job. These may be written as FORTRAN SUBROUTINE UFUNCT, VFUNCT, or WFUNCT. These SUBROUTINES may be invoked by a command card of the form:

GENERATE XXX UFUN YYY ZZZ AAA=N

where XXX, YYY, ZZZ, and AAA are arguments that might be passed to SUBROUTINE UFUNCT. Similarly, GENERATE XXX VFUN will result in a CALL to SUBROUTINE VFUNCT, and GENERATE XXX WFUN will invoke SUBROUTINE UFUNCT.

SCAT3 makes use of the above capability in the GENERATE SYSINT VFUN command. It is recommended that before one begins writing a user function, a FORTRAN programmer review the program listings, particularly SUBROUTINE VFUNCT and SUBROUTINE AMOS. It should be noted that the SPECTR portion of the SCAT3 code contains dummy versions of SUBROUTINE AMOS, UFUNCT, VFUNCT, and WFUNCT. For this reason, when one performs a LINKAGE EDIT to incorporate a new user function, the new SUBROUTINES must be loaded first. Numerous utility SUBROUTINES within the SPECTR coding may be used for arithmetic and bookkeeping functions. At such times, the listing for details and calling sequences should be consulted.

As a guide in writing a user function, a simple card-punching aid is described below. A listing of the FORTRAN statements can be found in Figure E-1.

The user function can be used to punch any spectral array element previously calculated or that is in the library, onto cards in the format used to enter a new element via an I/O READIN command. The element values will also be printed. The function will be invoked by the command:

GENERATE XXX WFUN FORM=N.

where XXX is the name of the array element (e.g., the AMOS output array code DH) and N is a format code. In addition to illustrating the writing of a user

function, the example may be of practical use.

The following steps are performed in this user function:

(a) Check the number of arguments.

(b) Use SPECTR function LOCATE to determine the position of the values for element XXX in COMMON/LIBRY/ARRAY(,) if the element name is not in the core data table, the disk library is searched and the element loaded into ARRAY.

(c) If the element cannot be located or if the mode is wrong; e.g., it has been defined as a constant instead of an array, an error message is generated.

(d) The LOW and HIGH positions in the element are determined, and the date is obtained from the system.

(e) Check the parameter "FORM =" for 1., 2., or 3. A code of 1 will use FORMAT (10G7.2) and a code of 2 will use FORMAT (10E7.2). Code 3 will use FORMAT(10F7.4), which may not be sufficient for some element values.

(f) Punch the array values.

(g) Print the array values.

The SUBROUTINE may be compiled and linkage-edited to SCAT3. The new subroutine must be loaded before SCAT3, which contains a dummy routine by that name. The JCL must be modified to include a card punch as device FT07F001.

Figure E-1

FORTRAN Listing of Sample User Function

```
                C
ISN 0002               SUBROUTINE WFUNCT(RESULT,PARS,NPAR)
                C
                C            USER FUNCTION TO PUNCH CARDS FROM ARRAY ELEMENT
                C          INVOKED VIA :  GENERATE XXX WFUN FORM=N.
                C             WHERE XXX = ARRAY ELEMENT NAME, & N IS FORMAT CODE
                C        N=1. (DEFAULT) 10G7.3
                C        N=2.           10E7.3
                C        N=3.           10F7.4  (USE WITH CARE..EASILY OVERFLOWED ! )
                C
ISN 0003               INTEGER RANGE(183,150)
ISN 0004               LOGICAL LOCATE
ISN 0005               REAL*8 RESULT,PARS(NPAR),FOURS
                C
ISN 0006               DIMENSION IDATE(2)
ISN 0007               COMMON/LIBRY/ARRAY(183,150),CONST(600)
ISN 0008               EQUIVALENCE (ARRAY(1,1),RANGE(1,1))
ISN 0009               COMMON/INPUT/STRING(80),LSTR,INFIL
                C
                C          # OF ARGUMENTS OK ?
ISN 0010               IF(NPAR.LE.1)GO TO 1
                C
ISN 0012           101 FORMAT('0',10X,'***  TOO MANY ARGUMENTS !'/'0')
ISN 0013               WRITE(6,101)
ISN 0014               RETURN
                C            GET ELEMENT WITH NAME "(RESULT)"
ISN 0015             1 IF(LOCATE(RESULT,JPOS,MODE)) GO TO 2
                C
ISN 0017           102 FORMAT('0',10X,'***   UNABLE TO LOCATE ',A8)
ISN 0018               WRITE(6,102)RESULT
ISN 0019               RETURN
                C            MODE OK ?
ISN 0020             2 IF(MODE.EQ.2)GO TO 3
                C
ISN 0022           103 FORMAT('0',10X,'***    ',A8,'  NOT AN ARRAY ELEMENT'/'0')
ISN 0023               WRITE(6,103)
ISN 0024               RETURN
                C            GET LOW & HIGH INDEX FOR ELEMENT (LAST 2 ARGUMENTS)
ISN 0025             3 LOW=RANGE(182,JPOS)
ISN 0026               IHIGH=RANGE(183,JPOS)
                C            CONVERT TO WAVELENGTH: (1) = 300 NANOMETERS
ISN 0027               LAML=295 + 5*LOW
ISN 0028               LAMH=295 + 5*IHIGH
                C            GET DATE FROM SYSTEM VIA SPECTR UTILITY
ISN 0029               CALL COMDAT(IDATE)
                C            CHECK FORMAT OPTION
ISN 0030               IFORM=1
ISN 0031               CALL SCALNM(STRING,80,' FORM=',6,F,&4)
                C            NOT REACHED IF "FORM=" NOT FOUND
ISN 0032               IFORM=IFIX(F+.1)
ISN 0033               IF((IFORM.GE.1).AND.(IFORM.LE.3)) GO TO 4
                C
ISN 0035               WRITE(6,104)F
ISN 0036           104 FORMAT('0',10X,'***    INVALID FORMAT CODE',F8.1,' (1.-3. OK)'/'0')
ISN 0037               RETURN
                C
```

Figure E-1 (Continued)

```
                        C              PUNCH HEADER
ISN 0038                      4 WRITE(7,105) RESULT,LAML,LAMH,IDATE
ISN 0039                    105 FORMAT('I/O READIN'/
                          1         A8,' VAL',6X,I4,6X,I4,40X,2A4)
                        C              GET FIRST 4 CHAR OF ELEMENT NAME "RESULT"
ISN 0040                        FID=RESULT
ISN 0041                        NCARD = (IHIGH-LOW)/10 + 1
ISN 0042                        I1=LOW
ISN 0043                        DO 8 N=1,NCARD
ISN 0044                        I2=I1+9
                        C              WHICH FORMAT ?
ISN 0045                        GO TO(5,5,7),IFORM
                        C
ISN 0046                    106 FORMAT(10G7.2,2X,A4,I4)
ISN 0047                      5 WRITE(7,106)(ARRAY(I,JPOS),I=I1,I2),FID,N
ISN 0048                        GO TO 8
ISN 0049                    107 FORMAT(10E7.2,2X,A4,I4)
ISN 0050                      6 WRITE(7,107)(ARRAY(I,JPOS),I=I1,I2),FID,N
ISN 0051                        GO TO 8
ISN 0052                    108 FORMAT(10F7.4,2X,A4,I4)
ISN 0053                      7 WRITE(7,108)(ARRAY(I,JPOS),I=I1,I2),FID,N
                        C
ISN 0054                      8 I1=I2+1
                        C
                        C              PRINT
ISN 0055                        WRITE(6,109)RESULT
ISN 0056                    109 FORMAT('1'/'0',10X,'PUNCHED ',A8/'0')
                        C          "RESULT" WILL BE PRINTED UPON RETURN
ISN 0057                        RETURN
ISN 0058                        END
```